**CHAPTER 13**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* liquids flow by sliding over one another and takes the shape of its container and resist compressive forces. Both liquids and gases can flow, so both are called fluids.

**Pressure**

• pressure = force/area

• Although the weight of both blocks is the same, the upright block exerts greater pressure against the table.

**Pressure in a Liquid**

When you swim under water,

• The pressure you feel is due to the weight of air/water above you.

• deeper water = greater pressure.

• The pressure a liquid exerts depends on its depth and density of the liquid.

Liquid pressure = weight density × depth

• If we neglect atmospheric pressure,

o at twice the depth, the liquid pressure against the bottom is twice as great;

o at three times the depth, the liquid pressure is threefold; and so on.

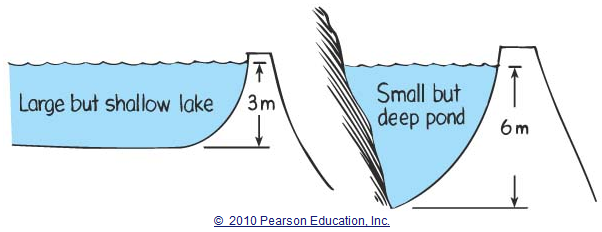
o Or, if the liquid is two or three times as dense, the liquid pressure is correspondingly two or three times as great for any given depth.

• the density of a liquid is the about the same at all depths except for changes due to temp.

• The total pressure of a liquid : weight density × depth + atmosphere pressure

• total pressure must be specified

• pressure does not depend on the amount of liquid present, only the depth.



• Volume is not the key—depth is. The average water pressure acting against the dam depends on the average depth of the water and not on the volume of water held back. The large, shallow lake exerts only one-half the average pressure that the small, deep pond exerts.

**Archimedes’ Principle**

• An immersed object is buoyed up by a force = weight of the fluid it displaces.

• If you stick your foot in water, it’s immersed. If immersion is total, you’re submerged

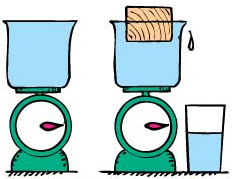
• an immersed object displaces 1 kilogram of fluid, the buoyant force acting on it is equal to the weight of 1 kilogram.

• This is because, at any depth, the container can displace no greater volume of water than its own volume.

• And the weight of this displaced water (not the weight of the submerged object!) is equal to the buoyant force.

• A liter of water occupies a volume of 1000 cm3, has a mass of 1 kg, and weighs 9.8 N. Its density may therefore be expressed as 1 kg/L and its weight density as 9.8 N/L. (Seawater is slightly denser, about 10.0 N/L).

• If we immerse it completely (submerge it), it will be buoyed up by a force equivalent to the weight of a full liter of water (1 kilogram of mass).

• If the container is fully submerged and doesn’t compress, the buoyant force will equal the weight of 1 kilogram of water at any depth.

If a 30-kilogram object displaces 20 kilograms of fluid upon immersion, its apparent weight will be equal to the weight of 10 kilograms (98 newtons). Note that, in Figure 13.13, the 3-kilogram block has an apparent weight equal to the weight of 1 kilogram when submerged. The apparent weight of a submerged object is its usual weight in air minus the buoyant force.

It makes no difference how deep the cube is placed because, although the pressures are greater with increasing depths, the difference between the pressure up against the bottom of the cube and the pressure down against the top of the cube is the same at any depth

Whatever the shape of the submerged body, the buoyant force is equal to the weight of fluid displaced.

Liquid pressure is the same for any given depth below the surface, regardless of the shape of the containing vessel. Liquid pressure = weight density × depth (plus the air pressure at the top).

• Pressure is depth dependent, not volume dependent, so we see that there is a reason why water seeks its own level.

• Roman aqueducts assured that water flowed slightly downhill from reservoir to city

• Some ancient pipe systems installed in Rome indicate that not all Romans believed that water couldn’t flow uphill.

• (fill a garden hose with water and holding the two ends at the same heigh and levels are equal.)( If one end is raised higher than the other, water will flow out of the lower end, even if it has to flow “uphill” part of the way)

• liquid pressure is exerted equally in all directions.

• Because a liquid can flow, the pressure is downward, sideways & upward.

• The bottom of a boat is certainly pushed upward by water pressure

• When liquid presses against a surface, there is a net force that is perpendicular to the surface. Although pressure doesn’t have a specific direction, force does.

• Components of the forces that are not perpendicular to the surface cancel each other out, leaving only a net perpendicular force at each point.

The forces of a liquid pressing against a surface add up to a net force that is perpendicular to the surface.

The force vectors act perpendicular to the inner container surface and increase with increasing depth.

**What Makes an Object Sink or Float?**

• buoyant force depends on volume of the object

• The buoyant force is = to weight of the volume of fluid displaced.

• Small objects displace small amounts = small buoyant forces.

• Large objects displace large amounts = larger buoyant forces.

• It is the volume of the submerged object—not its weight—that determines the buoyant force.

• The weight does affect floating.

• Whether an object will sink or float in a liquid depends on how the buoyant force compares with the object’s weight which depends on the object’s density.

• Consider these three simple rules:

1. An object more dense than the fluid in which it is immersed will sink.

2. An object less dense than the fluid in which it is immersed will float.

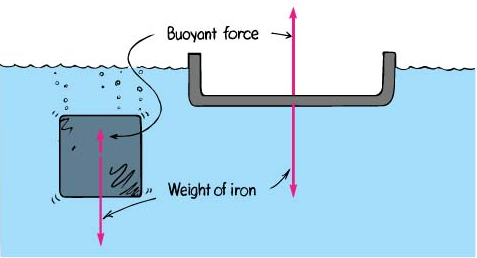
3. An object having a density equal to the density of the fluid in which it is immersed will neither sink nor float.

• diet soda float, and regular soda sink in water. What does this tell you about their relative densities?

• Wearing a life jacket increases volume while correspondingly adding very little to your weight. It reduces your overall density.

• For a submarine, weight, not volume, is varied to achieve the desired density. Water is taken into or blown out of its ballast tanks

• the overall density of a crocodile increases when it swallows stones. = swims lower in the water, thus exposing itself less to its prey



**Flotation**

An iron block sinks, while the same quantity of iron shaped like a bowl floats.

• Consider a 1-ton block of solid iron. Because iron is nearly eight times denser than water, it displaces only 1/8 ton of water when submerged, which is not enough to keep it afloat. Suppose we reshape the same iron block into a bowl. It still weighs 1 ton. But when we put it in water, it displaces a greater volume of water than when it was a block.

• When the buoyant force equals 1 ton, it will sink no farther.

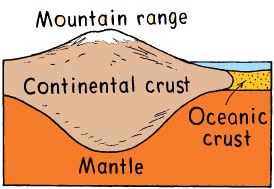
**principle of flotation:** When an object displaces a weight of fluid equal to its own weight, it floats. 

• If it displaces more, it rises; if it displaces less, it falls. If it displaces exactly its weight, it hovers at constant altitude.

•denser fluid = greater buoyant force than a less dense fluid.

• A ship, floats higher in salt water than in freshwater because salt water

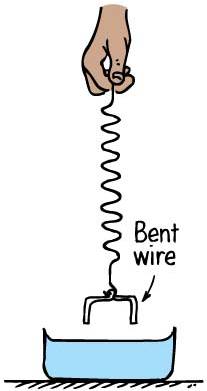
A floating object displaces a weight of fluid equal to its own weight



• **Pascal’s Principle**

• a change in pressure at one part of an enclosed fluid will be transmitted undiminished to other parts.

• force exerted on the left piston increases the pressure in the liquid and is transmitted to the right piston.

****• if the pressure of city water is increased at the pumping station by 10 units of pressure, the pressure everywhere in the pipes of the connected system will be increased by 10 units of pressure

• Fill a U-tube with water and place pistons at each end,. Pressure exerted against the left piston will be transmitted throughout the liquid and against the bottom of the right piston.

• The pressure that the left piston exerts against the water will be exactly equal to the pressure the water exerts against the right piston.

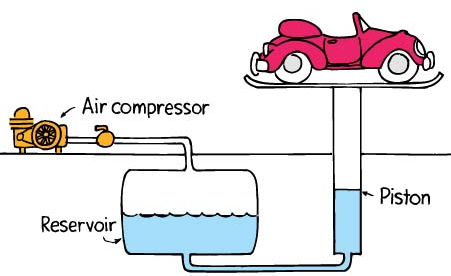
• Since there is 50 times the area, 50 times as much force is exerted on the larger piston. Thus, the larger piston will support a 500-kg load—fifty times the load on the smaller piston!

• Blaise Pascal is remembered scientifically for hydraulics

“Men never do evil so cheerfully and completely as when they do so from religious conviction.”

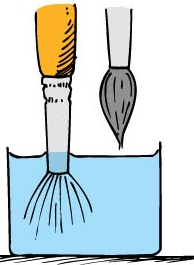
• The input force multiplied by the distance moved by the smaller piston is equal to the output force multiplied by the distance moved by the larger piston; this is one more example of a simple machine operating on the same principle as a mechanical lever.

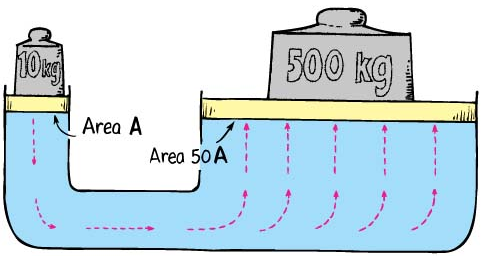
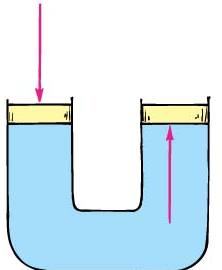
• Pascal’s principle applies to all fluids, whether gases or liquids.

• Hydraulics is employed by modern devices ranging from very small to enormous. Note the hydraulic pistons in almost all construction machines where heavy loads are involved (Figure 13.24)

• **Surface Tension**

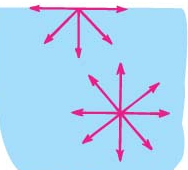
• This contractive tendency of the surface of liquids

• When the bent wire is lowered into the water and then raised, the spring will stretch because of surface tension.

• When the brush is taken out of the water, the hairs are held together by surface tension.

• accounts for the spherical shape of liquid drops.

• Sphere- the shape having the least surface area.

• the mist and dewdrops on spider are nearly spherical blobs. (The larger they are, the more that gravity flattens them.)

• Surface tension is caused by molecular attractions.

• each molecule is attracted in every direction by neighboring molecules, resulting in no tendency to be pulled in any specific direction.

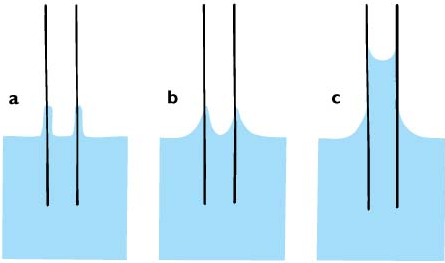
• A molecule on the surface of a liquid is pulled only by neighbors on each side and downward from below; there is no pull upward

• These molecular attractions thus tend to pull the molecule from the surface into the liquid, and this tendency minimizes the surface area.

• The water surface sags like a piece of plastic wrap, which allows certain insects, such as water striders, to run across the surface of a pond.

• The surface tension of water is greater than that of other common liquids,

• pure water has a stronger surface tension than soapy water. We can see this when a little soap film on the surface of water is effectively pulled out over the entire surface. This minimizes the surface area of the water. The same thing happens for oil or grease floating on water. Oil has less surface tension than cold water, and it is drawn out into a film covering the whole surface. But hot water has less surface tension than cold water because the faster-moving molecules are not bonded as tightly. This allows the grease or oil in hot soups to float in little bubbles on the surface of the soup. When the soup cools and the surface tension of the water increases, the grease or oil is dragged out over the surface of the soup. The soup becomes “greasy.” Hot soup tastes different from cold soup primarily because the surface tension of water in the soup changes with temperature.



• **Capillarity**

• The rise of a liquid in a fine, hollow tube or in a narrow space is capillarity.

• Bubble Master Tom Noddy blows bubbles within bubbles. The large bubble is elongated due to blowing, but it will quickly settle to a spherical shape due to surface tension

Water molecules stick to glass more than to each other. The attraction between unlike substances such as water and glass is called adhesion. The attraction between like substances, molecular stickiness, is called cohesion.

.

•

how oil soaks upward in a lamp wick and water soaks into a bath towel when one end hangs in water.

• Capillary action brings water to the roots of plants and carries sap and nourishment to high branches of trees.

Review Questions

1. Give two examples of a fluid.

Pressure

2. Distinguish between force and pressure.

Pressure in a Liquid

3. What is the relationship between liquid pressure and the depth of a liquid? Between liquid pressure and density?

4. If you swim beneath the surface in salt water, will the pressure be greater than in freshwater at the same depth? Why or why not?

5. How does water pressure one meter below the surface of a small pond compare with water pressure one meter below the surface of a huge lake?

6. If you punch a hole in a container filled with water, in what direction does the water initially flow outward from the container?

Buoyancy

7. Why does buoyant force act upward on an object submerged in water?

8. Why is there no horizontal buoyant force on a submerged object?

9. How does the volume of a completely submerged object compare with the volume of water displaced?

Archimedes’ Principle

10. How does the buoyant force on a submerged object compare with the weight of water displaced?

11. Distinguish between a submerged body and an immersed body.

12. What is the mass of 1 L of water? What is its weight in newtons?

13. If a 1-L container is immersed halfway into water, what is the volume of water displaced? What is the buoyant force on the container?

What Makes an Object Sink or Float?

14. Is the buoyant force on a submerged object equal to the weight of the object itself or equal to the weight of the fluid displaced by the object?

15. There is a condition in which the buoyant force on an object does equal the weight of the object. What is this condition?

16. Does the buoyant force on a submerged object depend on the volume of the object or the weight of the object?

17. Fill in the blanks: An object denser than water will \_\_\_\_\_\_ in water. An object less dense than water will \_\_\_\_\_\_ in water. An object with the same density of water will \_\_\_\_\_\_\_\_\_\_\_\_ in water.

18. How is the density of a fish controlled? How is the density of a submarine controlled?

Flotation

19. It was emphasized earlier that buoyant force does not equal an object’s weight but does equal the weight of displaced water. Now we say buoyant force equals the object’s weight. Isn’t this a grand contradiction? Explain.

20. What weight of water is displaced by a 100-ton ship? What is the buoyant force that acts on a floating 100-ton ship?

Pascal’s Principle

21. What happens to the pressure in all parts of a confined fluid if the pressure in one part is increased?

22. If the pressure in a hydraulic press is increased by an additional 10 N/cm2, how much extra load will the output piston support if its cross-sectional area is 50 cm2?

Surface Tension

23. What geometrical shape has the least surface area for a given volume?

24. What is the cause of surface tension?

Capillarity

25. Distinguish between adhesive and cohesive forces.

26. What determines how high water will climb in a capillary tube?

Projects

1. Place an egg in a pan of tap water. Then dissolve salt in the water until the egg floats. How does the density of an egg compare to that of tap water? To that of salt water?

2. If you punch a couple of holes in the bottom of a water-filled container, water will spurt out because of water pressure. Now drop the container, and, as it freely falls, note that the water no longer spurts out! If your friends don’t understand this, could you figure it out and then explain it to them?

3. Float a water-soaked Ping-Pong ball in a can of water held more than a meter above a rigid floor. Then drop the can. Careful inspection will show the ball pulled beneath the surface as both the ball and the can drop. (What does this say about surface tension?). More dramatically, when the can makes impact with the floor, what happens to the ball, and why? Try it and you’ll be astonished! (Caution: Unless you’re wearing safety goggles, keep your head away from above the can when it makes impact.)

4. Soap greatly weakens the cohesive forces between water molecules. You can see this by putting some oil in a bottle of water and shaking it so that the oil and water mix. Notice that the oil and water quickly separate as soon as you stop shaking the bottle. Now add some soap to the mixture. Shake the bottle again and you will see that the soap makes a fine film around each little oil bead and that a longer time is required for the oil to gather after you stop shaking the bottle.

This is how soap works in cleaning. It breaks the surface tension around each particle of dirt so that the water can reach the particles and surround them. The dirt is carried away in rinsing. Soap is a good cleaner only in the presence of water.

One-Step Calculations

Pressure = weight density × depth

Exercises

1.What common liquid covers more than two-thirds of our planet, makes up 60% of our bodies, and sustains our lives and lifestyles in countless ways?

2. Which is more likely to hurt—being stepped on by a 200-lb man wearing loafers or being stepped on by a 100-lb woman wearing high heels?

3. Which do you suppose exerts more pressure on the ground—an elephant or a lady standing on spike heels? (Which will be more likely to make dents in a linoleum floor?) Approximate a rough calculation for each.

4. Stand on a bathroom scale and read your weight. When you lift one foot up so that you’re standing on one foot, does the reading change? Does a scale read force or pressure?

5. Why are persons who are confined to bed less likely to develop bedsores on their bodies if they use a waterbed rather than an ordinary mattress?

6. You know that a sharp knife cuts better than a dull knife. Do you know why this is so? Defend your answer.

7. If water faucets upstairs and downstairs are turned fully on, will more water per second flow out of the upstairs faucets or the downstairs faucets?

8. The photo shows physics instructor Marshall Ellenstein walking barefoot on broken glass bottles in his class. What physics concept is Marshall demonstrating, and why is he careful that the broken pieces are small and numerous? (The Band-Aids on his feet are for humor!)

9. Why does your body get more rest when you’re lying down than it does when you’re sitting? And why is blood pressure measured in the upper arm, at the elevation of your heart? Is blood pressure in your legs greater?

10. When standing, blood pressure in your legs is greater than in your upper body. Would this be true for an astronaut in orbit? Defend your answer.

11. How does water pressure 1 meter beneath the surface of a lake compare with water pressure 1 meter beneath the surface of a swimming pool?

12. Which teapot holds more liquid?

13. The sketch shows a reservoir that supplies water to a farm. It is made of wood and is reinforced with metal hoops. (a) Why is it elevated? (b) Why are the hoops closer together near the bottom part of the tank?

14. A block of aluminum with a volume of 10 cm3 is placed in a beaker of water filled to the brim. Water overflows. The same is done in another beaker with a 10-cm3 block of lead. Does the lead displace more, less, or the same amount of water?

15. A block of aluminum with a mass of 1 kg is placed in a beaker of water filled to the brim. Water overflows. The same is done in another beaker with a 1-kg block of lead. Does the lead displace more, less, or the same amount of water?

16.A block of aluminum with a weight of 10 N is placed in a beaker of water filled to the brim. Water overflows. The same is done in another beaker with a 10-N block of lead. Does the lead displace more, less, or the same amount of water? (Why are your answers to this exercise and to Exercise 15 different from your answer to Exercise 14?)

17.In 1960, the U.S. Navy’s bathyscaphe Trieste (a submersible) descended to a depth of nearly 11 kilometers in the Marianas Trench near the Philippines in the Pacific Ocean. Instead of a large viewing window, it was a small circular window 15 centimeters in diameter. What is your explanation for so small a window?

18.There is a story about Pascal in which it is said that he climbed a ladder and poured a small container of water into a tall, thin, vertical pipe inserted into a wooden barrel full of water below. The barrel burst when the water in the pipe reached about 12 m. This was all the more intriguing because the weight of added water in the tube was very small. What two physical principles was Pascal demonstrating?

19.There is a legend of a Dutch boy who bravely held back the whole North Sea by plugging a hole in a dike with his finger. Is this possible and reasonable? (See also Problem 4.)

20.If you’ve wondered about the flushing of toilets on the upper floors of city skyscrapers, how do you suppose the plumbing is designed so that there is not an enormous impact of sewage arriving at the basement level? (Check your speculations with someone who is knowledgeable about architecture.)

21.Why does water “seek its own level”?

22.Suppose that you wish to lay a level foundation for a home on hilly and bushy terrain. How can you use a garden hose filled with water to determine equal elevations for distant points?

23.When you are bathing on a stony beach, why do the stones hurt your feet less when you’re standing in deep water?

24.If liquid pressure were the same at all depths, would there be a buoyant force on an object submerged in the liquid? Explain.

25.A can of diet soda floats in water, whereas a can of regular soda sinks. Explain this phenomenon first in terms of density, then in terms of weight versus buoyant force.

26.Why will a block of iron float in mercury but sink in water?

27.The mountains of the Himalayas are slightly less dense than the mantle material upon which they “float.” Do you suppose that, like floating icebergs, they are deeper than they are high?

28.Why is a high mountain composed mostly of lead an impossibility on the planet Earth?

29.How much force is needed to push a nearly weightless but rigid 1-L carton beneath a surface of water?

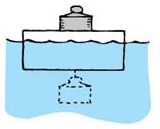
30.Why will a volleyball held beneath the surface of water have more buoyant force than if it is floating?

31.Why does an inflated beach ball pushed beneath the surface of water swiftly shoot above the water surface when relesed?

32.Why is it inaccurate to say that heavy objects sink and that light objects float? Give exaggerated examples to support your answer.

33.Why is the buoyant force on a submerged submarine appreciably greater than the buoyant force on it while it is floating?

34.A piece of iron placed on a block of wood makes it float lower in the water. If the iron were instead suspended beneath the wood, would it float as low, lower, or higher? Defend your answer.



35.Compared with an empty ship, would a ship loaded with a cargo of Styrofoam sink deeper into the water or rise in the water? Defend your answer.

36.If a submarine starts to sink, will it continue to sink to the bottom if no changes are made? Explain.

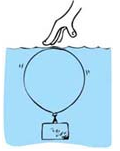
37.A barge filled with scrap iron is in a canal lock. If the iron is thrown overboard, does the water level at the side of the lock rise, fall, or remain unchanged? Explain.

38.Would the water level in a canal lock go up or down if a battleship in the lock sank?

39.Will a rock gain or lose buoyant force as it sinks deeper in water? Or will the buoyant force remain the same at greater depths? Defend your answer.

40. Will a swimmer gain or lose buoyant force as she swims deeper in the water? Or will her buoyant force remain the same at greater depths? Defend your answer, and contrast it with your answer to Exercise 39.

41. A balloon is weighted so that it is barely able to float in water. If it is pushed beneath the surface, will it return to the surface, stay at the depth to which it is pushed, or sink? Explain. (Hint: Does the balloon’s density change?)



42. The density of a rock doesn’t change when it is submerged in water, but your density changes when you are submerged. Explain.

43. In answering the question of why bodies float higher in salt water than in freshwater, your friend replies that the reason is that salt water is denser than freshwater. (Does your friend often answer questions by reciting only factual statements that relate to the answers but don’t provide any concrete reasons?) How would you answer the same question?

44. A ship sailing from the ocean into a freshwater harbor sinks slightly deeper into the water. Does the buoyant force on the ship change? If so, does it increase or decrease?

45. Suppose that you are given the choice between two life preservers that are identical in size, the first a light one filled with Styrofoam and the second a very heavy one filled with gravel. If you submerge these life preservers in the water, upon which will the buoyant force be greater? Upon which will the buoyant force be ineffective? Why are your answers different?

46. The weight of the human brain is about 15 N. The buoyant force supplied by fluid around the brain is about 14.5 N. Does this mean that the weight of fluid surrounding the brain is at least 14.5 N? Defend your answer.

47. The relative densities of water, ice, and alcohol are 1.0, 0.9, and 0.8, respectively. Do ice cubes float higher or lower in a mixed alcoholic drink? What comment can you make about a cocktail in which the ice cubes lie submerged at the bottom of the glass?

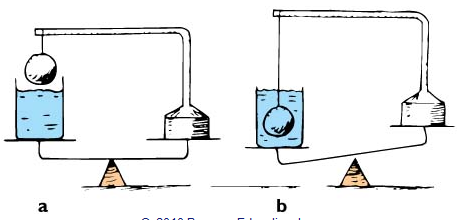
48. When an ice cube in a glass of water melts, does the water level in the glass rise, fall, or remain unchanged? Does your answer change if the ice cube has many air bubbles? How about if the ice cube contains many grains of heavy sand?

49. When the wooden block is placed in the beaker, what happens to the scale reading? Answer the same question for an iron block.



50. A half-filled bucket of water is on a spring scale. Will the reading of the scale increase or remain the same if a fish is placed in the bucket? (Will your answer be different if the bucket is initially filled to the brim?)

51. The weight of the container of water, as shown in a, is equal to the weight of the stand and the suspended solid iron ball. When the suspended ball is lowered into the water, as shown in b, the balance is upset. Will the additional weight needed on the right side to restore balance be greater than, equal to, or less than the weight of the solid iron ball?



52. If the gravitational field of the Earth were to increase, would a fish float to the surface, sink, or stay at the same depth?

53. What would you experience when swimming in water in an orbiting space habitat where simulated gravity is g? Would you float in the water as you do on Earth?

54. We say that the shape of a liquid is that of its container. But, with no container and no gravity, what is the natural shape of a blob of water? Why?

55. If you release a Ping-Pong ball beneath the surface of water, it will rise to the surface. Would it do the same if it were inside a big blob of water floating weightless in an orbiting spacecraft?

56. So you’re on a run of bad luck, and you slip quietly into a small, quiet pool as hungry crocodiles lurking at the bottom are relying on Pascal’s principle to help them to detect a tender morsel. What does Pascal’s principle have to do with their delight at your arrival?

57. In the hydraulic arrangement shown, the larger piston has an area that is fifty times that of the smaller piston. The strong man hopes to exert enough force on the large piston to raise the 10 kg that rest on the small piston. Do you think he will be successful? Defend your answer.

58. In the hydraulic arrangement shown in Figure 13.22, the multiplication of force is equal to the ratio of the areas of the large and small pistons. Some people are surprised to learn that the area of the liquid surface in the reservoir of the arrangement shown in Figure 13.23 is immaterial. What is your explanation to clear up this confusion?

59. Why will hot water leak more readily than cold water through small leaks in a car radiator?

60. On the surface of a pond, it is common to see water striders, insects that can “walk” on the surface of water without sinking. What physics concept explains their ability?

Problems

1. The depth of water behind the Hoover Dam in Nevada is 220 m. What is the water pressure at the base of this dam? (Neglect the pressure due to the atmosphere.)

2. A 6-kg piece of metal displaces 1 liter of water when submerged. What is its density?

3. A rectangular barge, 5 m long and 2 m wide, floats in freshwater. (a) Find how much deeper it floats when its load is a 400-kg horse. (b) If the barge can only be pushed 15 cm deeper into the water before water overflows to sink it, how many 400-kg horses can it carry?

4. A dike in Holland springs a leak through a hole of area 1 cm2 at a depth of 2 m below the water surface. How much force must a boy apply to the hole with his thumb to stop the leak? Could he do it?

5. A merchant in Kathmandu sells you a solid-gold 1-kg statue for a very reasonable price. When you return home, you wonder whether or not you got a bargain, so you lower the statue into a container of water and measure the volume of displaced water. What volume will verify that it’s pure gold?

6. When a 2.0-kg object is suspended in water, it “masses” 1.5 kg. What is the density of the object?

7. An ice cube measures 10 cm on a side and floats in water. One cm extends above water level. If you shaved off the 1-cm part, how many cm of the remaining ice would extend above water level?

8. A swimmer wears a heavy belt to make her average density exactly equal to the density of water. Her mass, including the belt, is 60 kg. (a) What is the swimmer’s weight in newtons? (b) What is the swimmer’s volume in m3? (c) At a depth of 2 m below the surface of a pond, what buoyant force acts on the swimmer? What net force acts on her?

9. A vacationer floats lazily in the ocean with 90% of his body below the surface. The density of the ocean water is 1,025 kg/m3. What is the vacationer’s average density?

10. In the hydraulic pistons shown in the sketch, the small piston has a diameter of 2 cm. The larger piston has a diameter of 6 cm. How much more force can the larger piston exert compared with the force applied to the smaller piston?

